HEU MATERIAL SUMMARY
12.1 MTU HEU Down-blending Requirement

This section presents information summarizing the 12.1 metric tonnes (MT)highly enriched uranium (HEU) materials to be provided for down-blending to low enriched uranium (LEU) under this Contract. Table 1 presents the quantities of materials by material grouping. The summary data in this table was compiled using historical information and analytical data for the materials which is considered the best available information at this time. The assay range of material is between 20% and 95% in the Uranium-235 isotope. The number of items and mass information for some material groupings will change due to DOE processing required to size-reduce and/or prepare the materials for packaging and shipment. In addition, material exchanges may also cause small changes within or between the material groupings such as the number of items, assay, and mass information during execution of the project.

Table 1 Summary of HEU Materials;
Mass by Material Grouping, kg

	Mass, kg		
Material Grouping	**Net**	**Uranium**	**U-235**
Unalloyed Metal	5611	5608	4469
Alloyed Metal	3958	3394	3047
Oxides	4395	2912	1949
Compounds	620	187	164
Sources and Standards	23	18	12
Reactor Fuel	386	30	26
Totals	14992	12148	9667

HEU MATERIAL SUMMARY
12.1 MTU HEU Down-blending Requirement (continued)

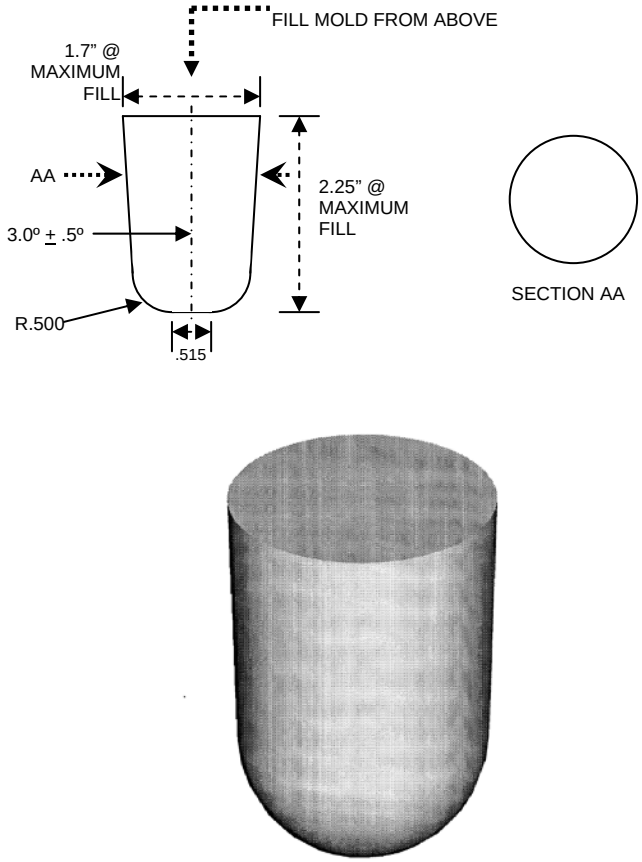
UNALLOYED METAL

Unalloyed Metal is uranium metal with trace quantities of elemental impurities. It is estimated that 75% of the Unalloyed Metal will require chemical purification. Some of the remainder will require cross-blending to reduce trace quantities of transuranics and fission products, and elemental contaminants in order to meet the ASTM specification for commercial nuclear fuel when down-blended. The Unalloyed Metal materials are unirradiated; the source of the trace quantities of transuranics and fission products is contamination from reprocessing at other DOE facilities as part of the DOE fuel cycle.

The Unalloyed Metal will be provided either as cast slugs or as broken metal. The unalloyed metal is considered homogenous. The broken metal is produced by breaking hollow cylindrical castings into smaller pieces to facilitate packing into cans. These small pieces of broken castings are sized to fit in either a 4 - 4 ¼ inch diameter by 4 3/8 inch or 8 ¾ inch high can and may be up to ~ 0.75″ x 1.5″ x 3″ in dimension. Each piece typically ranges between 80 and 300 grams. Cans are lined with wire mesh to protect the can surfaces. The slug castings are small, cylindrical-shaped castings. Slug sizes will vary, are not uniform in dimensions and may be irregularly shaped. Nominal dimensions are up to 1.7″ in diameter and up to 2.3″ tall. The nominal weight of each size of slug is up to 1.6 kg. Figure 1 describes the maximum size of cast slug provided under this work.

HEU MATERIAL SUMMARY
12.1 MTU HEU Down-blending Requirement (continued)

FIGURE 1: CAST SLUG



ALLOYED METAL

Alloyed Metal is uranium metal that has been alloyed with elements such as titanium, stainless steel, aluminum, and zirconium up to one weight percent. These materials contain trace quantities of elemental impurities and will require chemical purification and/or blending in order to meet the ASTM specification for commercial nuclear fuel when down-blended. The Alloyed Metal materials are also unirradiated and may also contain trace quantities of transuranics and fission products. Metal will be provided either as cast slugs as described above or as broken metal.

HEU MATERIAL SUMMARY
12.1 MTU HEU Down-blending Requirement (continued)

OXIDES

The Oxides grouping consists of nine (9) categories of oxide-type materials:

1. Crucible Skull Oxide: Uranium oxide residues from castings and molds. The oxides are typically in the form of U_3O_8 and will contain large amounts of carbon as well as traces of other materials such as erbium or yttrium. Some of these oxides resulted from the casting of various alloyed metals; therefore, the presence of elements such as molybdenum up to 10 weight percent, and aluminum, chromium, iron, nickel, titanium, and zirconium up to one weight percent are expected.
2. Other Oxide: Predominantly uranium carbide-pyrolytic carbon (UC_2). Other items include carbides and uranium oxides mixed with graphite, rag ash (carbides and U oxides mixed with graphite), U_3O_8 special samples mixed with unusual elements, and U_3O_8 mixed with other metal oxides.
3. Black Oxide: Typically U_3O_8 produced from burning of machine turnings and saw fines from both alloyed and unalloyed metals.
4. Impure Oxide: Various, low-grade uranium oxides containing impurities from recovery processes.
5. Dioxide: Uranium dioxide (UO_2).
6. Trioxide: Uranium trioxide (UO_3).
7. Ceramic Dioxide: Uranium dioxide produced at a high temperature to specific specifications.
8. Mixed Oxide: Uranium oxides of various compounds and/or enrichments.
9. Clinkers and Screenings: Small pieces of uranium metal and alloys, as well as large U_3O_8 particles screened from the casting process.

Quantities of each category of oxide are listed in Table 2. It is assumed that all oxide materials will require chemical purification in order to meet the ASTM specification for commercial nuclear fuel when down-

HEU MATERIAL SUMMARY
12.1 MTU HEU Down-blending Requirement (continued)

blended.

Table 2. Oxide Categories; Mass, kg

	Skull Oxide	*Other Oxide*	*Black oxide*	*Impure Oxide*	*Dioxide*	*Trioxide*	*Ceramic Dioxide*	*Mixed Oxide*	*Clinkers&Screenings*	**Totals**
Net Wt.	2013	243	336	316	237	30	4	160	1057	4396
Uranium Wt.	1562	118	213	124	59	23	3	27	783	2912
U-235 Wt.	1086	108	95	78	44	11	1	15	511	1949

COMPOUNDS

This material grouping is comprised of mixed uranium compounds which are typically of low purity but can be readily converted to “usable” uranium. These items consist of “known” quantities of uranium and U-235. A list of expected compounds includes uranium peroxide, ammonium diuranate, vacuum cleanings, uranyl fluoride, and purified nitrate crystals. It is assumed that all uranium compounds will require chemical purification in order to meet the ASTM specification for commercial nuclear fuel when down-blended, except for the purified nitrate crystals.

SOURCES AND STANDARDS

Sources and Standards were used to calibrate instrumentation. These items consist of “known” quantities of uranium and U-235 encapsulated within a metal or alloy casing. The encapsulating material is not chemically or metallurgically bonded to the uranium, so the encapsulating material can be removed thus exposing the uranium. It is assumed that some of these materials will require chemical purification in order to meet the ASTM specification for commercial nuclear fuel when down-blended.

REACTOR FUEL

The Reactor Fuel material grouping consists of a variety of reactor fuel and reactor fuel related materials. The Reactor Fuel materials are summarized in Table 3 below. It

HEU MATERIAL SUMMARY
12.1 MTU HEU Down-blending Requirement (continued)

should be assumed that all of these materials will require purification in order to meet the ASTM specification for commercial nuclear fuel.

The Reactor Fuel materials consist primarily of plates and rods. The MTR-type plates are typically U_3O_8 mixed with aluminum powder compressed and clad between aluminum plates, and are near 93% enrichment. Some of the reactor fuel contains other elements such as zirconium or boron.

When possible, reactor fuel materials will be provided in their current form. In some cases, the fuel materials may be size-reduced to facilitate packaging into the ES-3100 shipping containers or may be shipped in an appropriate container (e.g., the ES-4100, a replacement for the 110-gallon 6M, should the package become available).

The U.S. Government represents that the reactor fuel materials will be only slightly irradiated or unirradiated. Such slight irradiation consists of the following:

- Maximum of 10^{-8} grams of plutonium per gram ^{235}U.
- Maximum fission product activity of 10^{-3} millicurie per gram ^{235}U.
- Maximum beta radiation level of five (5) millirem per hour at one (1) inch, or one (1) millirem per hour at one (1) foot from the surface of the fuel materials.
- Maximum gamma radiation level of two (2) millirem per hour at one (1) inch, or one (1) millirem per hour at one (1) foot from the surface.

Reactor Fuel materials will not exceed the aforementioned levels unless otherwise negotiated with the Contractor prior to shipment.

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12.1 MTU HEU Down-blending Requirement

Table 3 Reactor Fuel Summary

			Weight, g			Irradiation History	
Reactor	**Fuel Form**	**Item count**	**Net**	**U**	**U-235**	**None**	**Slight**
ARMF Idaho	Plates, plate tray	52	89248	3394	3162	X	X
BR2 (Belgium)	Plates	29	187030	15196	13659		X
Bulk Shielding Reactor (ORNL)	Unirradiated fuel assembly scrap plates produced for the Bulk Shielding Reactor. U3O8 outer and inner plates made of uranium/aluminum alloy, and control rods.	18	3309	3423	3020	X	
CNEA RA-2 (Argentina)	Bundles of MTR-type plates	35	78536	3716	3342	X	
Miscellaneous	Plate	1	24197	1793	1670	X	
PBF PWR	INL PWR Rod standards	4	3107	2196	1405	X	
Reactor Fuel Summary		**139**	**385427**	**29538**	**26258**		

[1] **Some material carries peaceful use foreign obligations between the United States and the European Union and will require special reporting.**

HEU MATERIAL SUMMARY
HEU for Unallocated LEU Reserve

SHIPPING CONTAINER SUMMARY

Type B shipping containers, predominately the ES-3100 shipping container, will be used to ship the HEU materials under this contract. Shipping containers must be returned to the Y-12 National Security Complex for reuse. Other Type B shipping containers may also be used as appropriate as described in the reactor fuel section above. When appropriate for the materials being shipped, shipping containers will contain three to six (3 to 6) cans with nominal diameter of 4 - 4.25 inches. Cans typically have press-fit or ring clamp lids and may have a lifting bail to facilitate loading and removal. Tables 4A and 4B list the different heights of the cans that will be used and the number of cans that will be in the shipping containers. After unloading, cans are to be disposed of by the Contractor. Also note that polyethylene or Teflon bottles may also be used and shall be disposed of by the Contractor.

Table 4A. Convenience Cans and Bottles.

	Nominal Convenience Cans Height (in)				Bottles	
HEU Form	**4.375**	**4.875**	**8.75**	**10**	**Poly[1]**	**Teflon[2]**
Unalloyed Metal	X	X	X			
Alloyed Metal		X	X			
Oxides		X	X	X	X	X
Compounds			X	X	X	X
Sources and Standards			X	X		

Notes:
1. Poly bottles may be used for shipping "Other Oxides."
2. Teflon bottles used for shipping uranyl nitrate crystals.
3. For metal, sample bottles, vials, or convenience cans containing a drilled sample pack may be inerted with argon. The lids for the inerted containers will have clips holding the lids in place.

HEU MATERIAL SUMMARY
HEU for Unallocated LEU Reserve (continued)

Table 4B. Maximum Number of Cans and Bottles Per Shipping Container.

	Nominal Convenience Cans Height (in)				Bottles	
Container	**4.375**	**4.875**	**8.75**	**10**	**Poly**	**Teflon**
ES-3100	5	5	3	3	3	3

HEU MATERIAL SUMMARY
HEU for Unallocated LEU Reserve (continued)

ANALYTICAL SUMMARIES FOR UNALLOYED METAL AND OXIDES

Tables 5 and 6 are summaries of analytical data from samples of metal and oxide materials that have been previously processed. These data are representative of the HEU materials to be provided under this Contract. Since most of the materials to be provided have not yet been processed, sampled and analyzed, the data in the tables indicate the range and mean levels of various constituents that may be expected in the HEU. Much of the material will be further processed, sampled and/or analyzed during Contract execution; however, the total quantity of metal or oxide estimated to require chemical purification is not expected to increase.

HEU MATERIAL SUMMARY
HEU for Unallocated LEU Reserve (continued)

Table 5. Summary Data for Metal (1969 samples).

Item	Units	Max	Min	Median	Mean	Std Dev
U	wt %	100.00%	85%[1]			
U-232	µg/gU	0.00705	0.00000	0.00000	0.00013	0.00038
U-234	µg/gU	10,970	1,270	9,870	7,837	2,773
U-235	wt %	95%	20%			
U-236	µg/gU	24,120	780	3,560	4,228	3,702
Tc-99	µg/gU	3.19	0.00	0.00	0.01	0.09
TRU	Bq/gU	13,191.0	0.0	12.9	171.8	498.1
FPGamma	MeV Bq/gU	577	0	0	2	27
Al	µg/gU	5,650.0	0.3	10.0	14.4	127.7
Sb	µg/gU	2.0	0.0	0.3	0.5	0.5
As	µg/gU	15.0	0.0	0.3	1.4	2.9
Ba	µg/gU	84.0	0.0	0.3	0.6	2.2
Be	µg/gU	41.0	0.0	0.3	0.4	1.2
Bi	µg/gU	1.0	0.0	0.3	0.4	0.3
B	µg/gU	115.0	0.1	0.3	1.4	7.6
Br	µg/gU	506.0	0.0	5.0	6.1	14.6
Cd	µg/gU	2.0	0.0	0.3	0.3	0.1
Ca	µg/gU	1300.0	0.0	0.6	4.4	34.6
C	µg/gU	979.0	6.0	407.0	390.9	122.1
Cs	µg/gU	1.0	0.0	0.3	0.3	0.2
Cl	µg/gU	973.0	0.0	7.0	9.0	35.6
Cr	µg/gU	1000.0	0.3	11.0	12.6	23.9
Co	µg/gU	91.0	0.0	0.3	0.7	2.6
Cu	µg/gU	105.0	0.3	5.0	5.6	5.6
Dy	µg/gU	17.0	0	0.3	0.3	0.5
Er	µg/gU	233.0	0.0	0.3	2.8	12.5
Eu	µg/gU	1.0	0.0	0.3	0.3	0.1
F	µg/gU	71.0	0.0	7.0	6.8	4.1
Gd	µg/gU	3.0	0	0.3	0.3	0.1
Hf	µg/gU	0.0	0	0.3	0.4	0.3
Fe	µg/gU	1,934.0	0.3	79.0	86.7	78.4
Pb	µg/gU	4.0	0.0	0.3	0.7	1.1
Li	µg/gU	10.0	0.0	0.3	0.4	0.4
Mg	µg/gU	51.0	0.1	0.3	0.9	2.4

HEU MATERIAL SUMMARY
HEU for Unallocated LEU Reserve (continued)

Item	Units	Max	Min	Median	Mean	Std Dev
Mn	µg/gU	69.0	0.3	3.0	3.8	3.6
Hg	µg/gU	7.0	0.0	0.5	0.6	0.3
Mo	µg/gU	273.0	0.0	23.0	26.0	26.2
Ni	µg/gU	270.0	0.3	36.0	38.2	23.6
Nb	µg/gU	20.0	0.0	0.3	2.0	5.1
P	µg/gU	1000.0	0.2	7.0	20.9	46.0
K	µg/gU	202.0	0.0	0.3	2.4	7.2
Ru	µg/gU	2.0	0.0	0.3	0.4	0.2
Sm	µg/gU	2.0	0.0	0.3	0.3	0.2
Se	µg/gU	10.0	0.0	2.0	1.8	1.1
Si	µg/gU	1,500.0	0.3	95.0	124.7	108.3
Ag	µg/gU	410.0	0.0	0.3	0.8	13.3
Na	µg/gU	94.0	0.0	0.3	1.4	4.5
Sr	µg/gU	20.0	0.0	0.3	2.3	5.9
S	µg/gU	260.0	0.2	10.0	15.5	23.0
Ta	µg/gU	230.0	0.1	0.3	2.4	12.9
Th	µg/gU	78.0	0.0	1.8	2.4	6.7
Sn	µg/gU	12.0	0.0	0.3	1.4	2.9
Ti	µg/gU	94.0	0.3	0.8	1.8	4.5
W	µg/gU	899.0	0.0	40.0	45.7	50.9
V	µg/gU	10.0	0.0	0.3	0.5	0.6
Zn	µg/gU	34.0	0.0	0.3	1.7	3.3
Zr	µg/gU	500.0	0.2	4.0	9.8	21.5
TMI	µg/gU	6,916.3	0.0	855.1	864.6	314.3
EBC	µgEB/gU	117.5	0.0	2.5	3.4	7.6

[1] Includes alloyed metal.

HEU MATERIAL SUMMARY
HEU for Unallocated LEU Reserve (continued)

Table 6. Summary Data for Oxide (976 samples).

Item	Units	Max	Min	Median	Mean	Std Dev
U	wt %	86.24%	5.81%			
U-232	µg/gU	0.01269	0.00000	0.00000	0.00007	0.00056
U-234	µg/gU	11,850	1,220	6,415	6,197	3,144
U-235	wt %	95%	20%			
U-236	µg/gU	202,480	310	3,240	3,524	9,016
Tc-99	µg/gU	1,879.48	0.00	0.00	7.25	78.48
TRU	Bq/gU	2,465.8	0.0	58.1	121.6	236.6
FPGamma	MeV Bq/gU	369.0	0.0	0.0	1.0	15.0
Al	µg/gU	2,300.0	1.0	56.0	113.3	184.6
Sb	µg/gU	1,000.0	0.1	0.3	6.3	42.4
As	µg/gU	36.0	0.0	0.3	0.9	2.6
Ba	µg/gU	1,600.0	0.1	1.8	31.0	114.0
Be	µg/gU	700.0	0.0	2.0	9.5	40.3
Bi	µg/gU	34.0	0.1	0.2	0.6	1.7
B	µg/gU	1,400.0	0.1	7.0	50.4	138.2
Br	µg/gU	660.0	0.1	0.4	6.3	32.8
Cd	µg/gU	240.0	0.1	0.3	3.7	15.2
Ca	µg/gU	1,500.0	1.3	62.0	211.7	305.3
C	µg/gU	374,000.0	13.0	5,420.0	19,407.7	36,581.3
Cs	µg/gU	19.0	0.0	0.2	0.5	1.3
Cl	µg/gU	2,470.0	0.6	19.0	83.5	177.9
Cr	µg/gU	11,000.0	1.0	20.0	101.2	407.5
Co	µg/gU	697.5	0.0	1.0	6.0	30.5
Cu	µg/gU	6500.0	0.3	14.0	123.0	403.4
Dy	µg/gU	30.0	0.2	0.6	1.3	2.5
Er	µg/gU	470,000.0	0.2	3.0	4,753.5	33,226.6
Eu	µg/gU	14.0	0.1	0.3	0.6	1.0
F	µg/gU	1490.0	0.1	2.5	41.4	129.5
Gd	µg/gU	160.0	0.2	0.8	1.5	5.6
Hf	µg/gU	2,400.0	0.2	1.0	41.8	144.2
Fe	µg/gU	23,000.0	0.7	120.0	305.0	968.6
Pb	µg/gU	780.0	0.1	0.8	14.4	57.0
Li	µg/gU	315.1	0.0	1.0	5.2	22.4
Mg	µg/gU	4,700.0	0.1	13.3	73.5	229.5

HEU MATERIAL SUMMARY
HEU for Unallocated LEU Reserve (continued)

Item	Units	Max	Min	Median	Mean	Std Dev
Mn	µg/gU	1,200.0	0.2	10.0	46.3	116.5
Hg	µg/gU	94.0	0.2	0.7	1.4	3.6
Mo	µg/gU	3,900.0	0.1	18.0	52.7	161.9
Ni	µg/gU	1,100.0	1.3	36.1	88.5	165.9
Nb	µg/gU	2,200.0	0.0	0.3	12.5	87.0
P	µg/gU	1,000.0	0.1	17.0	59.1	137.4
K	µg/gU	2,700.0	0.1	15.0	87.0	209.4
Ru	µg/gU	71.0	0.1	0.4	1.6	4.7
Sm	µg/gU	29.0	0.2	0.6	1.1	2.3
Se	µg/gU	130.0	0.0	0.2	1.7	7.7
Si	µg/gU	3,500.0	10.0	201.4	297.4	293.1
Ag	µg/gU	880.0	0.1	0.6	3.9	31.2
Na	µg/gU	2,400.0	0.1	13.0	80.1	207.2
Sr	µg/gU	460.0	0.0	0.8	8.8	34.1
S	µg/gU	32,300.0	0.3	32.0	206.7	1213.1
Ta	µg/gU	5,100.0	0.1	1.4	17.0	177.5
Th	µg/gU	4,500.0	0.1	0.6	36.5	184.9
Sn	µg/gU	810.0	0.1	2.0	21.8	62.4
Ti	µg/gU	1,300.0	0.2	8.2	36.5	119.3
W	µg/gU	1,101.9	0.0	7.0	35.5	103.9
V	µg/gU	320.0	0.0	1.0	6.3	16.7
Zn	µg/gU	1,500.0	0.1	5.0	42.9	131.6
Zr	µg/gU	16,000.0	0.4	23.0	113.8	610.5
TMI	µg/gU	603,870.1	209.5	4,565.8	18,792.0	45,081.1
EBC	µgEB/gU	6,421.7	1.8	15.9	96.0	368.2